

# **STUDY OF DECAYING DC REMOVAL TECHNIQUES**

**A THESIS SUBMITTED IN PARTIAL  
FULFILLMENT OF THE REQUIREMENTS**

**FOR THE DEGREE OF**

**BACHELOR OF TECHNOLOGY IN ELECTRICAL  
ENGINEERING**

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**CERTIFICATE**

*This is to certify that the thesis entitled “STUDY OF DECAYING DC REMOVAL TECHNIQUES” submitted by Abhishek Singh & Pravin Katwe in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Electrical Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by them under my supervision and guidance.*

*To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma.*

*DATE-08/05/10*

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# ***Chapter 1***

## INTRODUCTION

## **1.1Introduction:-**

When any fault occurs in power system, current component contains fundamental component & DC decaying component (combination of decaying component & harmonics component).

DC offset is an offsetting of a signal from zero. This term originated in electronics field, as a direct current voltage, but the technique used to represent a waveform.

DC offset is the mean amplitude of the waveform; if the value of mean amplitude is zero, there is no DC offset. DC offset is quite undesirable.

In this thesis we have studied the DC decaying component estimation techniques.

Techniques are

1-Lowpass Highpass Filtering technique.

2- Kalman Filtering technique

3-FIR/IIR Filtering technique



## **1.2Review:-**

### **1. Lowpass & Highpass filter Technique:-**

#### **Lowpass Filter Technique:-**

It is a filter that reduces the amplitude of signal with frequency higher than cutoff frequency when low frequency signal is passed through the filter.

#### **Highpass Filter Technique:-**

It is the opposite of lowpass filter. It reduces the amplitude of signal with frequency lower than cutoff frequency when high frequency signal is passed through the filter.

### **2. Kalman Filtering Technique:-**

Kalman Filtering technique used to design the state space model of plant, process with noise measurement block. It provide the optimum solution of continues or discrete estimation problems.

### **3. FIR/IIR Filtering Technique:-**

**FIR Filter-**The linear phase characteristic within passband of filter in any filtering problem that time only it is in use.

**IIR Filter-**It requires less complex structure, less parameters & quite safer. That's why it is better than FIR filter.

The nature of problems & specification of required frequency response decides the use of FIR/IIR filters.

### **1.3Need for these techniques:-**

Relay doesn't sense the dc decaying component. Because of that many a times system faces problems. To overcome those problems we are introducing few techniques which are less costly, safer & having lesser complexity structure.

There are many methods to remove the dc decaying component like least error square method (LES), using DFT method. But there are many problems in these 2 methods.

In Least error square method technique there are so much calculations, looks so complex method. It takes so much time. Hence it is time taking method.

In DFT method, it doesn't even sense the dc decaying component. It allows fault signal to pass through it & sends fault signal to protective power system. Because of that some part of power system get disturbed & damaged.

Thus to overcome these problems we have introduced few easier, less complex techniques to remove the dc decaying component from fault current.

# ***Chapter 2***

Lowpass/Highpass filtering Technique

## 2.1 Background:-

### (A) Lowpass Filter

#### Definition:-

A low-pass filter circuit offers easy transit to low-frequency signals and difficult transit to high-frequency signals.

It is a filter that reduces the amplitude of signal with frequency higher than cutoff frequency when low frequency signal is passed through the filter.

#### Simple Circuit for Lowpass Filter:-

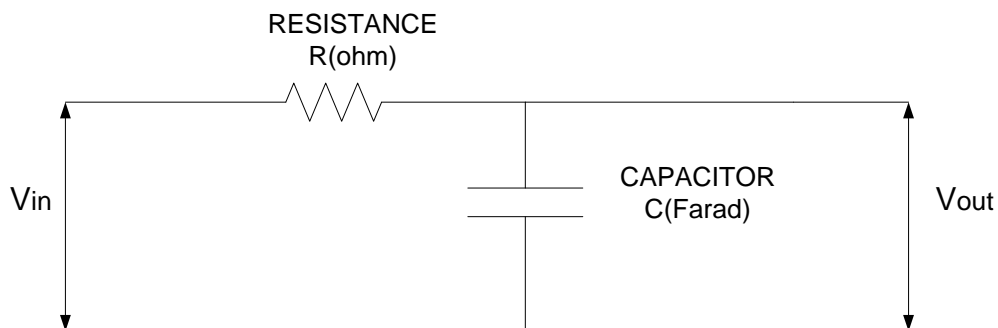


Fig2.1-Simple Lowpass RC Filter

#### Role of Lowpass Filter:-

In this technique, we have created a Digital FIR model. We used here a Lowpass filter block in order to remove the high frequency noise. Lowpass filter is also known as high cut filter.

## B)Highpass Filter

### Definition:-

A high-pass filter's task is just the opposite of a low-pass filter. It offers easy transit to high-frequency signal and difficult transit to a low-frequency signal.

It is the opposite of lowpass filter. It reduces the amplitude of signal with frequency lower than cutoff frequency when high frequency signal is passed through the filter.

### Simple circuit for Highpass Filter:-

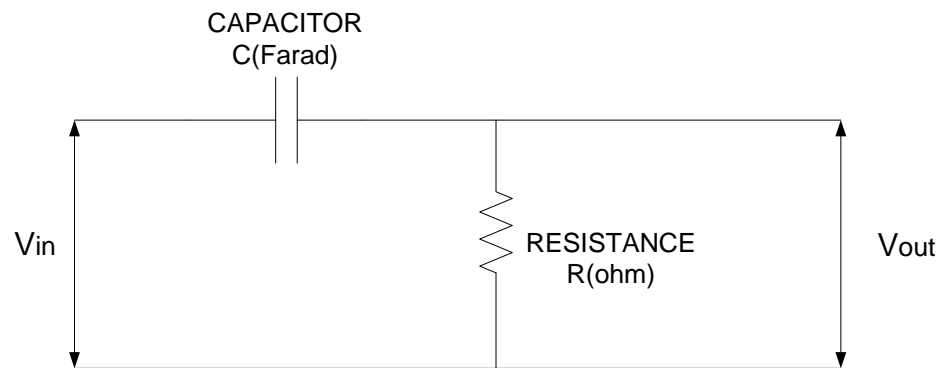


Fig2.2-Simple Highpass RC Filter

### Role of Highpass Filter:-

We use the Highpass Filter block to build a model that removes high frequency noise from signal. In this model, use the Highpass Filter is excited using random signal to create high frequency noise. It is also called low cut filter.

## 2.2 Simulink model implementation in MATLAB

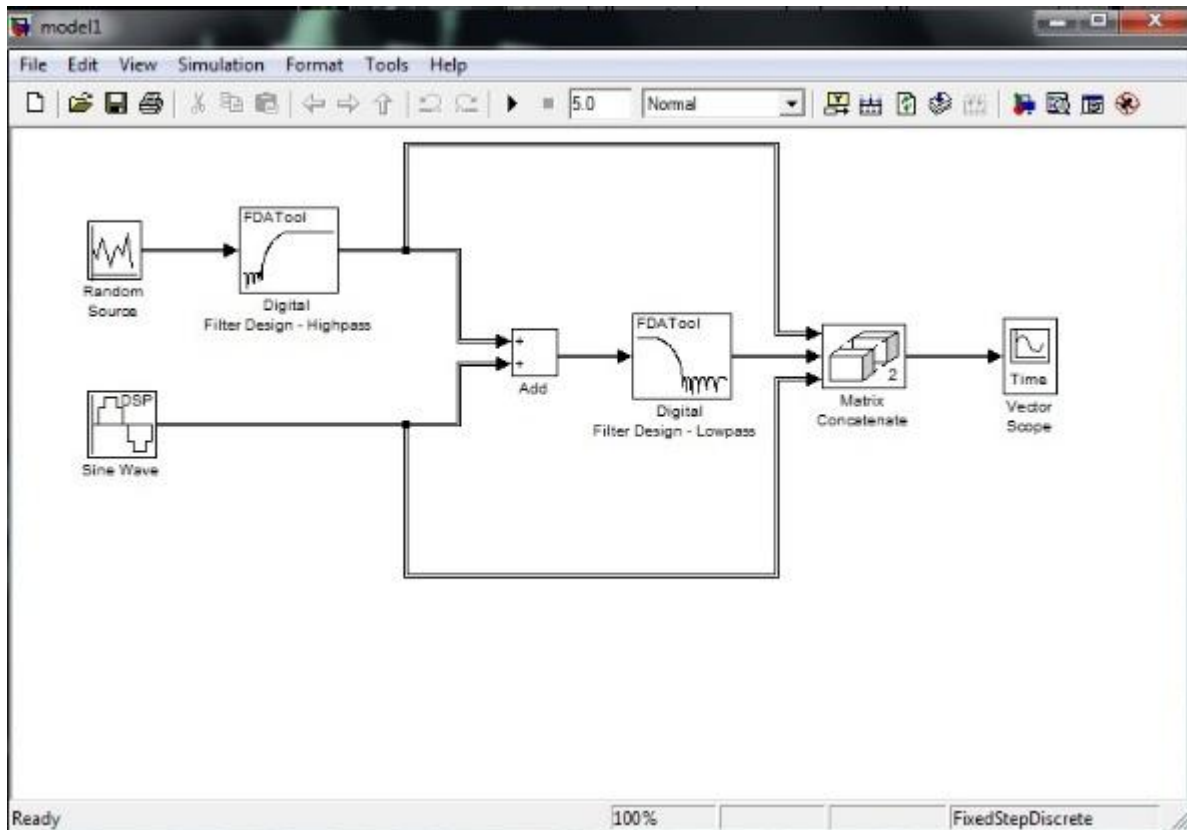


Fig2.3- Digital FIR Model contains blocks of Lowpass Filter & Highpass Filter

### 2.4 Working of the simulink model :-

In this simulink model, from random source we inject the signal to Lowpass filter. The random source signal is not necessary the sinusoidal. Lowpass filter reduces the amplitude of signal with frequency higher than cutoff frequency when low frequency signal is passed through the filter. Thus the signal From sine wave block & from lowpass filter gets added with the help of ADD block. From ADD block the resultant signal pass through the highpass filter. Highpass filter reduces the amplitude of signal with frequency lower than cutoff frequency when high frequency signal is passed through the filter. Then signal from Highpass filter, lowpass filter & the sinewave injected to matrix

concatenate. Matrix concatenate joins all the 3 signals & results a new signal. The resultant new signal i.e the filtered noisy sine wave signal can be analyze in vector scope.

## 2.4 PARAMETER SETTING

BLOCK	PARAMETER SETTING
<b>ADD</b>	*Icon shape=Rectangular *List of signs=++
<b>Matrix Concatenate</b>	*No. of inputs=3 *Mode=Multidimensional Array *Concatenate Dimension=2
<b>Random Source</b>	*Source type=Uniform *Minimum=0 *Maximum=4 *Sample mode=Discrete *Sample time=1/1000 *Samples per frame=50
<b>Sine Wave</b>	*Frequency(Hz)=75 *Sample Time=1/1000 *Samples per frame=50
<b>Vector Scope</b>	*Input Domain=Time *Time display span (no. of frames )=1

## 2.5 MATLAB simulink result & analysis

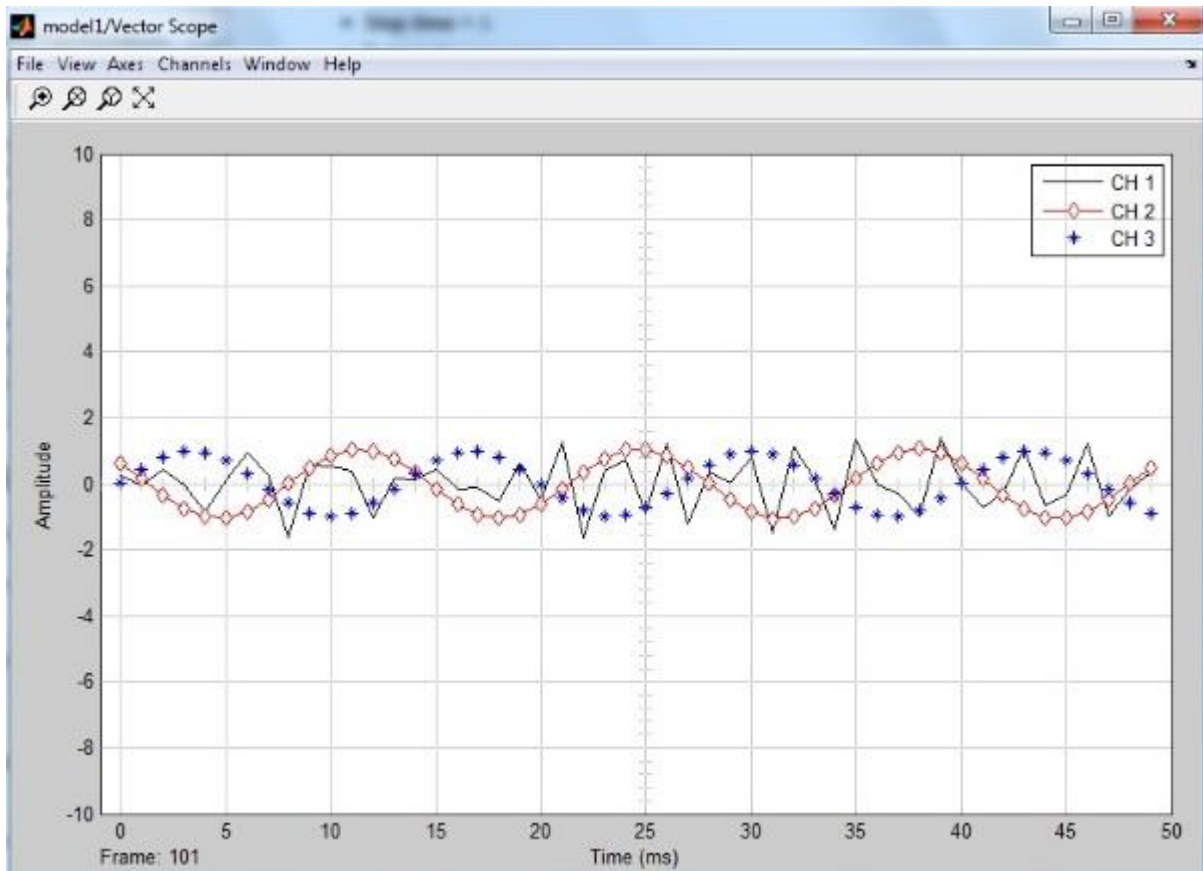


Fig2.4-MATLAB simulink result waveform

NOTE:-

Channel 1: Sine wave containing Noise (-----)

Channel 2: **Filtered waveform** (--o—o—o—o--)

Channel 3: **Fundamental sine wave** (---\*---\*---)



## 2.6 Result Analysis :-

In the output waveform; we can analyze that the filtered noisy sine waveform (Channel 2 signal) get filtered by the low/ High pass filtering technique. Where Channel 3 waveform is the original sine wave. Channel 1 waveform is the Noisy sine wave which is the combination of fundamental component of signal & the harmonic or the dc decaying component of signal.

With the help of Low/Highpass filtering technique we can successfully remove the dc offset component & get the fundamental component of signal which doesn't contain any harmonics or fault.

This technique is quite cheaper, less complex structure & safer.

NOTE:-

Channel 1: Sine wave containing Noise (-----)

Channel 2: **Filtered waveform** (--o—o—o—o--)

Channel 3: **Fundamental sine wave** (---\*---\*---)

# ***Chapter 3***

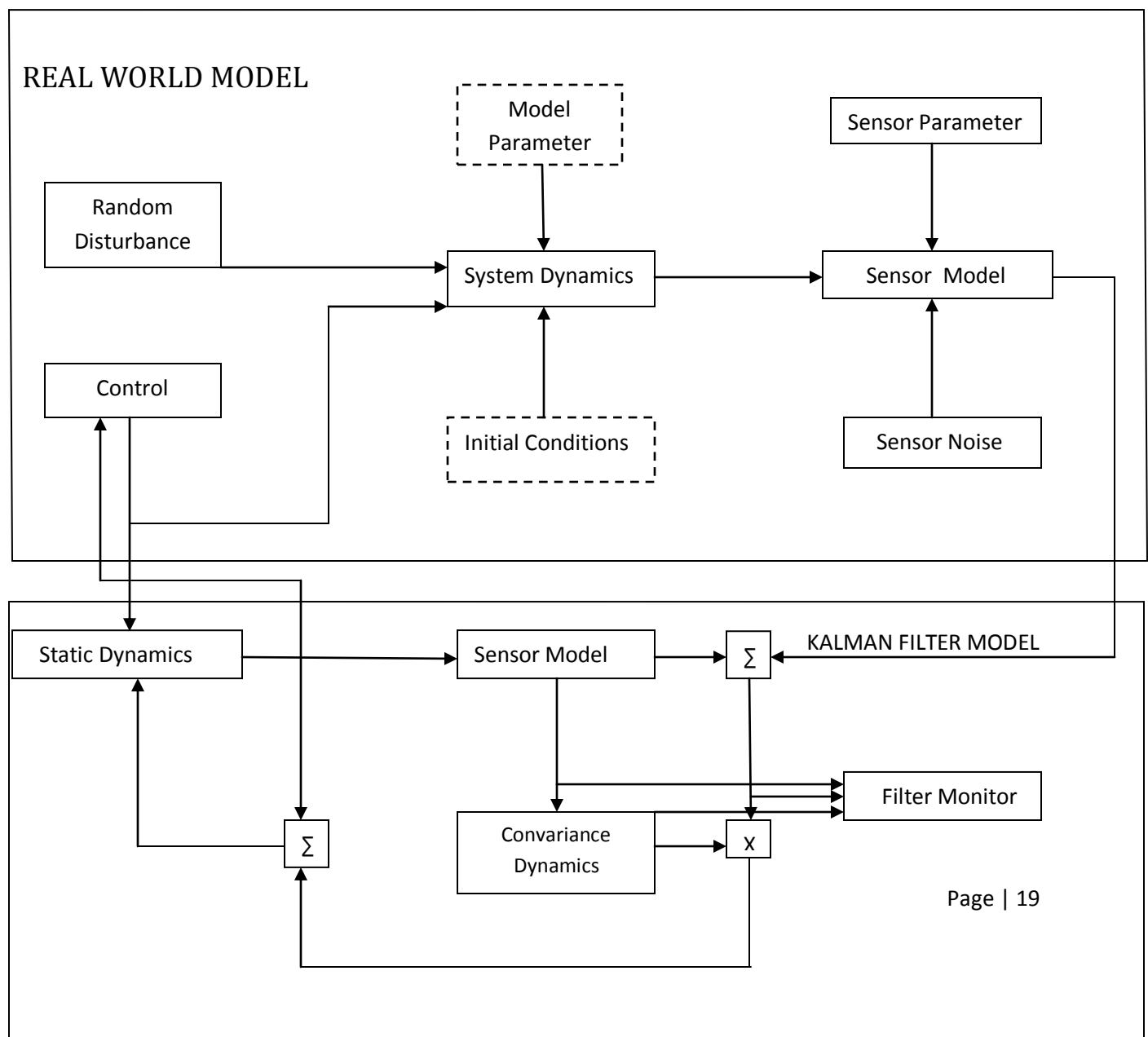
## Kalman Filtering Technique

### 3.1 Background:-

Kalman Filter came into picture in 1960 after Roudolph E. Kalman. Kalman filter is the estimator for linear quadratic problem. Problems are generally to estimate the instantaneous state of dynamic system.

It provides solution to the discrete/ continuous dynamic problem.

### 3.2 Schematic of Kalman Filter implementation:-



### 3.3 Simulation & design of Kalman Filter:-

Let us consider the case of steady state kalman Filter

Let us consider the discrete plant:-

$$x[n+1] = A1x[n] + B1(I[n] + g[n]) \dots\dots\dots (\text{State Equation})$$

$$y[n] = C1x[n] \dots\dots\dots (\text{Measurement Equation})$$

Consider here that the plant contains Gaussian noise  $g[n]$  with input  $I[n]$ .

Gaussian noise  $g[n]$  can be defined as the noise disturbance amplitude that is Gaussian in nature.

Lets considers the constant term A,B & C are

$$A1 = \begin{bmatrix} 1.127 & -0.540 & 0.113 \\ 1.000 & 0 & 0 \\ 0 & 1.000 & 0 \end{bmatrix};$$

$$B1 = \begin{bmatrix} -0.383 \\ 0.592 \\ 0.519 \end{bmatrix};$$

$$C1 = [1 \ 0 \ 0];$$

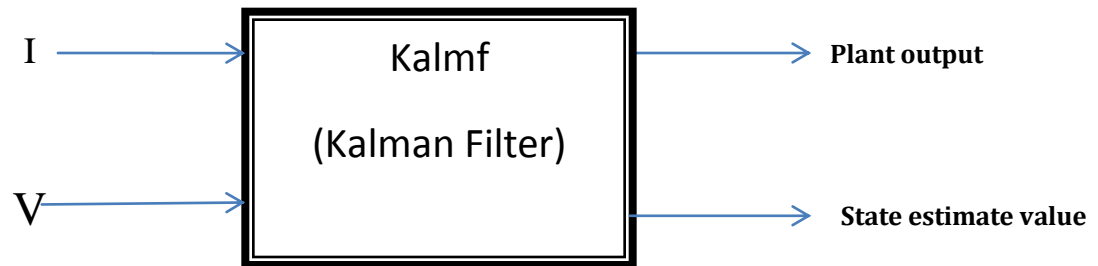
Our aim is to develop a Kalman filter that calculates the output result  $y[n]$  under the given input  $I[n]$  & the noisy output estimated value .

Whereas Noisy estimated value can be written as:

$$y[n] = C1x[n] + W[n]$$

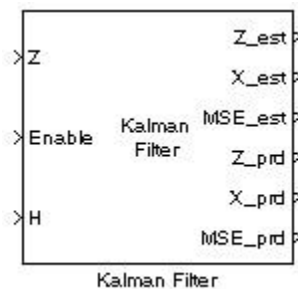
where  $W[n]$  is Gaussian white noise.

The inputs of kalman filter are I and V, and Output of kalman filter are the plant output value and state estimates value.



**Fig.3.1-Kalman Filter**

### 3.4 Kalman filter block representation in MATLAB:-



**Fig3.2 Kalman Filter in MATLAB**

In the input terminal there are 3 pins (Z, Enable & H) & 6 the output terminals are Z\_est, X\_est, MSE\_est, Z\_prd, X\_prd & MSE\_prd.

### 3.5 Block diagram representation to remove the dc decaying component

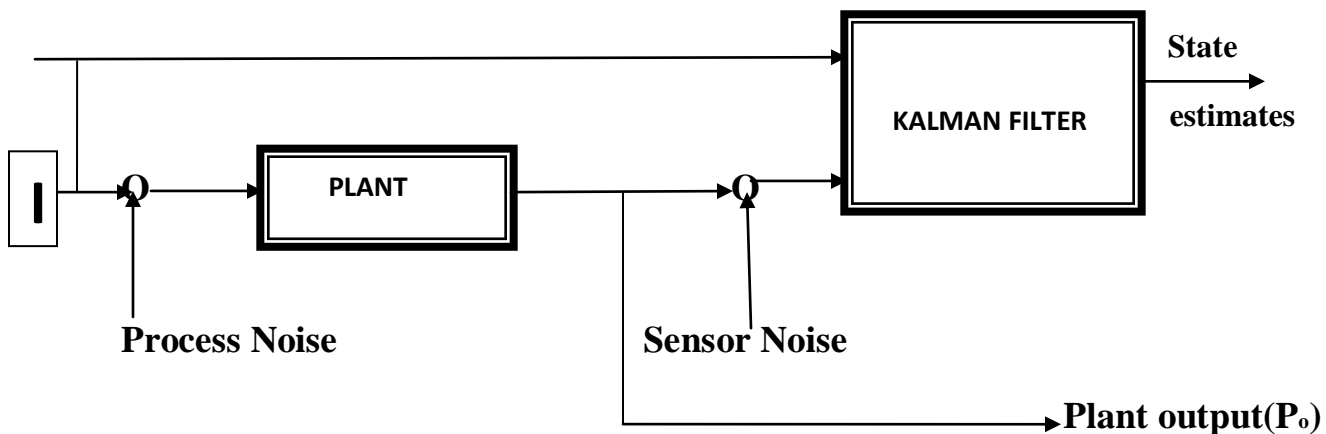


Fig3.3-block diagram representation of kalman filtering technique

This is the block diagram representation of kalman filtering technique. In this technique, our main aim is to compare the value of error before filtering & after filtering. So that from the calculation we can justify whether this technique is really filtering out the dc decaying component or NOT.

Here we are having Process Noise: Process noise is nothing but the random signal, the signal that contains equal power under the certain bandwidth.

Input value  $I(n)$  under the presence of process noise are passed through the plant, then plant out is passed through kalman filter under the presence of sensor noise. Then kalman filter output i.e the state estimates value & plant input value are compared to check the error difference & to check the technique whether this technique is beneficial or NOT.

Here we have taken some assumptions for easy calculation.

### 3.6 Analysis of Kalman filtering technique in MATLAB Simulink:-

#### In Matlab Simulink:-

```
%Steady state design of kalman filter
% Let us consider the process noise Pn & the sensor noise Sn.
% Let the complete model is a set of (plant + noise model).
Plant = ss(A1,[B1 B1],C1,0,-1,'inputname',{'I' 'G'},'outputname','Po');

%Define the process noise Pn value:
Pn = 2.5;
%Define the sensor noise Sn value:
Sn = 1;
% Now define the steady-state case of Kalman filter in equations
%
%  $x[n+1|n] = A1x[n|n-1] + B1u[n]$  (state equation)
%
%  $x[n|n] = x[n|n-1] + M (y[n] - C1x[n|n-1])$  (Measurement equation)
%
% where M = gain
Q = 1; R = 1;
[kalmf,L,P,M,Z] = kalman(Plant,Pn,Sn);
kalmf = kalmf(1,:);
M % gain
M =
0.37
0.08
-0.25
% Let us define a plant model with inputs K,L,O &
% outputs are P & R:
a' = A1;
b' = [B1 B1 0*B1];
c' = [C1;C1];
d' = [0 0 0;0 0 1];
P = ss(a',b',c',d',-1,'inputname',{'K' 'L' 'O'},'outputname',{'P' 'R'});

% Connect the defined model in parallel with kalman filter
```

```
sys = parallel(P,kalmf,1,1,[],[]);
```

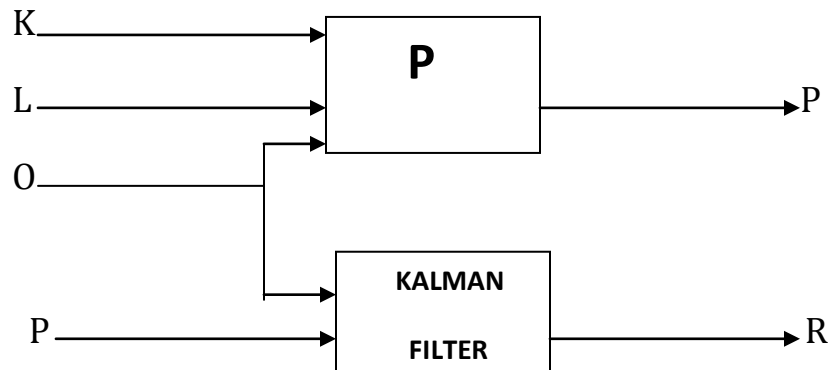


Fig3.4- Block diagram Parallel connection of plant model & kalman filter

```
SimModel.inputname
```

```
ans=
```

```
'K'
'L'
'O'
```

```
SimModel.outputname
```

```
ans=
```

```
'P'
'R'
```

```
% Lets us define the time limit & the input value
```

```
 $\beta = [0:100]'$ ;
```

```
I = sin( $\beta/5$ );
```

```
% define process noise and sensor noise:
```

```
randn('seed',0);
```

```
L = sqrt(Ps)*randn(length(t),1);
```

```
O = sqrt(Ns)*randn(length(t),1);
```

```
%here we will compare the response with the filtered response:
```



```

clf
subplot(211), plot(t,y,'b',t,P,'r--'),
xlabel('No. of samples'), ylabel('Output')
title('Kalman filter response')
subplot(212), plot(t,P(error),'g',t,R,'r--'),
xlabel('No. of samples'), ylabel('Error')

```

%On comparing we found that the value before filtering=1.12

%After filtering=0.26

### 3.7 MATLAB simulink result & analysis

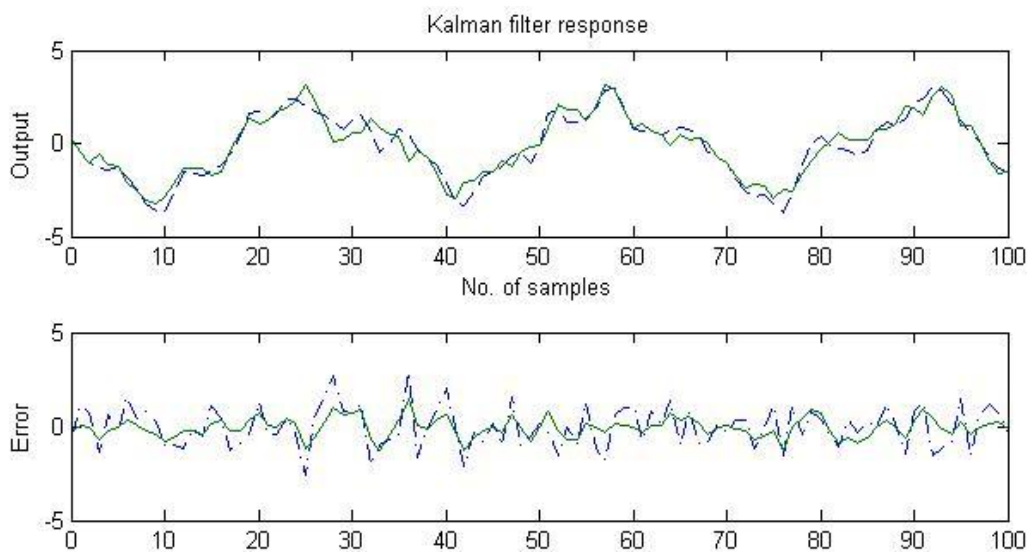


Fig.3.5 Comparison of two plots before/After filtering

### 3.8 Result Analysis:-

From above plots we can conclude that the the 2<sup>nd</sup> graph which is obtained after filtering has error value=0.26 & 1<sup>st</sup> graph before filtering has error value=1.12.

From the error value we can assure that the kalman filtering technique method is also successful method to calculate/eliminate the dc decaying/error component .

This methods includes mathematical equations therefore these methods are rarely used.

# ***Chapter 4***

Brief study of different linear system window techniques

## **4.1 Introduction:-**

In this chapter we will discuss in brief about the different FIR windows in digital FIR filter system & their different characteristics like their time domain response & frequency domain response.

## **4.2 Types of window:-**

There are many types of windows in digital FIR/IIR Linear system. Some of them are given below:-

1-Hamming Window

2-Gaussian Window

3-Hanning Window

4. Blackman Window.

Among all 4 Blackman Window has less leakage property therefore blackman window is quite preferable in linear system.

### 4.2.1 Hamming Window:-

The basic equation of hamming window coefficient is given by:-

$$w(n)=0.54-0.46\cos(2\pi n/N-1)....0<n<N$$

To create this window we will use Window Visualization tool. Let us create 65 point Hamming window:

```
P=65;  
wvtool(hamming(P))
```

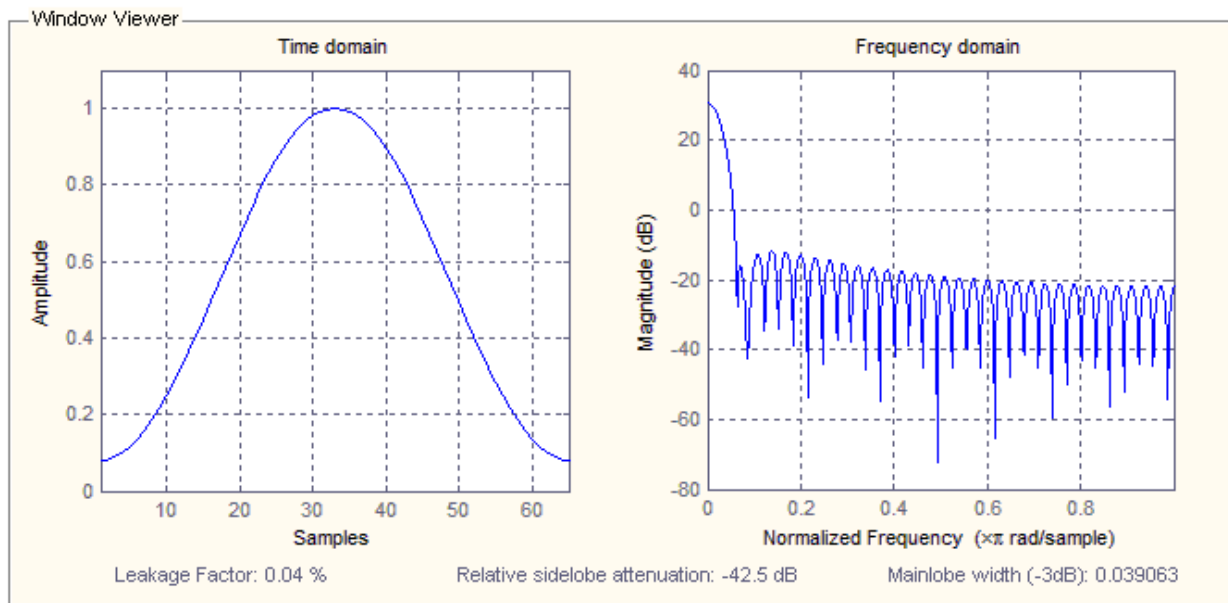


Fig.4.1 Hamming window characteristics

From window visualization we can analyze the time domain & frequency domain of 65 point Hamming window technique.

### 4.2.2 Gaussian Window:-

The coefficient of Gaussian window is given by:-

$$w(n) = \exp(-0.5\alpha n/N-2) \dots -N/2 < n < N/2$$

where N is N no. of point Gaussian window,  $\alpha$  is reciprocal of Standard deviation. Width is inversely related to  $\alpha$ .

To create this window we will use Window Visualization tool. Let us create 65 point Gaussian window:

```
P=65;  
wvtool(gausswin(P))
```

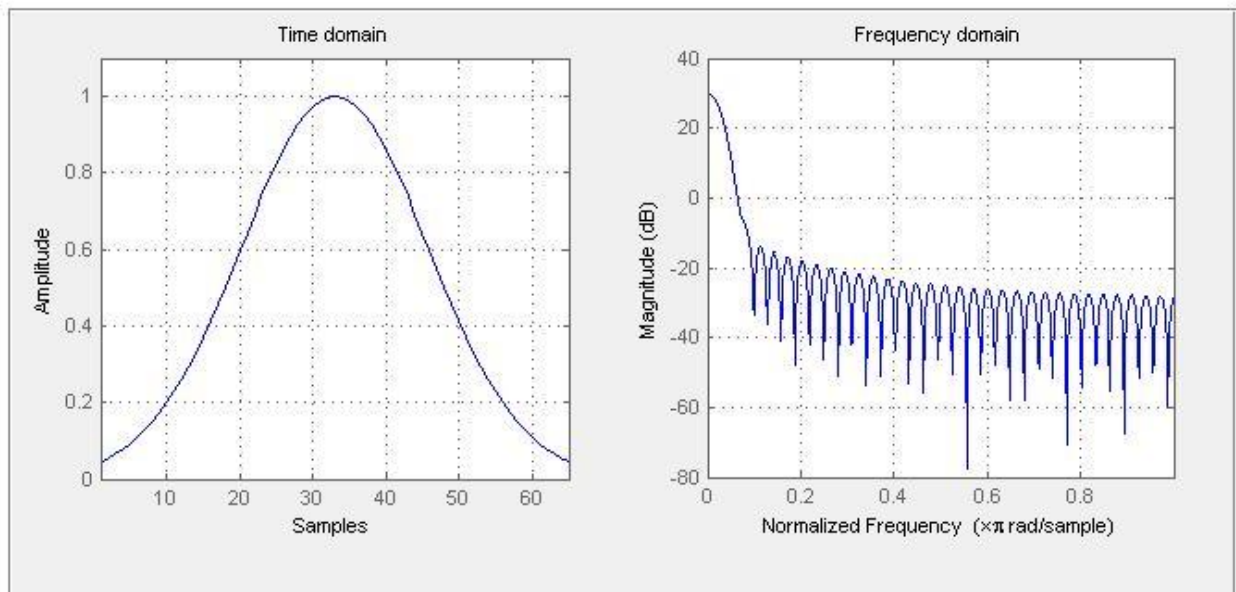


Fig.4.2 Gaussian window characteristics

If we compare the frequency response of the both the windows. We will find that the Gaussian frequency response is slight down as compared to hamming.

### 4.2.3 Hamming Window:-

The coefficient of Gaussian window is given by:-

$$w(n)=0.5(1-\cos(2\pi n/N)), \dots 0 \leq n < N$$

Window Length  $L = N+1$

To create this window we will use Window Visualization tool. Let us create 65 point Hanning window:

```
P=65;  
wvtool(hann(P))
```

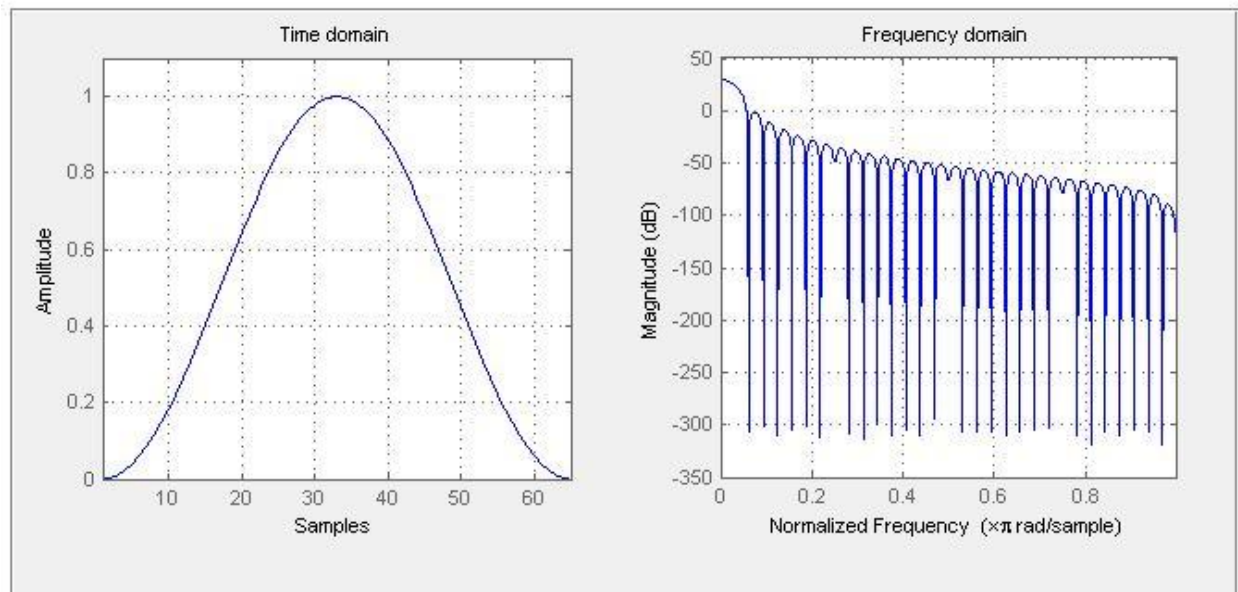


Fig:4.3 Hanning Window Characteristic

In this window scheme also the frequency response is quite different from rest of the other window techniques. Although the time domain response remains same.

#### 4.2.4 Blackman Window:-

The coefficient of blackman window is given by:

$$w(n)=0.42-0.5\cos(2\pi n/N)+0.08\cos(4\pi n/N)\dots\dots\dots 0<n<N$$

Length of the window is  $L=N+1$

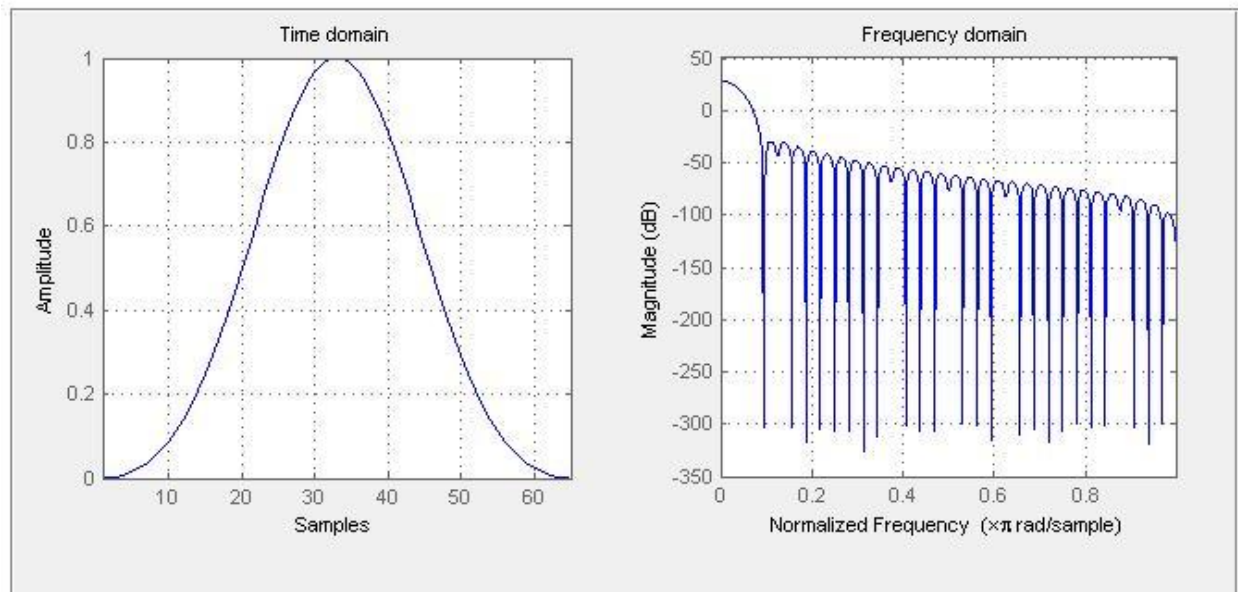


Fig.4.4 Blackman Window characteristics

It has less leakage than the hann & hamming window. It is preferably used rather than other windows.

Time domain response is quite different from the rest of the other window techniques responses.

Blackman window is generally used for the audio purpose work.



# ***Chapter 5***

## **Final Conclusions**

## **Conclusions:-**

*This thesis has demonstrated the techniques through which we can estimate the dc decaying component from the fault current/fault signal.*

- *In Low/Highpass Filter Technique we found that it was the easiest method to estimate the dc decaying component. The result analysis shows that we have estimated the dc decaying component correctly.*
- *In Kalman Filter Technique we found that it's full of mathematical operation. Kalman filter was designed using state equation & measurement equation. We have considered here the steady state condition.*
- *In last chapter, we have discussed about the brief introduction about the different kinds of window that are present in linear system. And analyzed the different responses i.e the time domain response & frequency domain response & compared the responses of different window techniques.*

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